Reported antibiotic use in 90 swine farms in Alberta

Andrijana Rajić, Richard Reid-Smith, Anne E. Deckert, Catherine E. Dewey, Scott A. McEwen

Abstract — Antibiotic use was described using a convenience sample of 90 Alberta swine farms representing approximately 25% of the Alberta market swine production. Data on the use of antibiotics were collected through an on-farm interview questionnaire. The vast majority of antibiotics were used in feed. The chlortetracycline/sulfamethazine/penicillin combination and tylosin were the most frequently used in-feed antibiotics in weaners and growers/finishers, respectively. The use of antibiotics through water was reported mostly occasionally in all categories. The use of injectable antibiotics was reported mostly in sick pigs. Penicillin was the most common in-water and injectable antibiotic in all categories. The apparent low frequency of critically important antimicrobials for use in humans (quinolones and 3rd generation cephalosporins) is an encouraging finding from a public health perspective. The widespread and frequently reported use of penicillin and tetracycline are of public health concern considering that both antimicrobials are also used for therapeutic purposes in human medicine.

Résumé — Rapport sur l'utilisation d'antibiotiques dans 90 porcheries de l'Alberta. L'utilisation d'antibiotiques a été décrite à l'aide d'un échantillon pratique de 90 porcheries d'Alberta représentant approximativement 25 % du marché albertain de la production porcine. Les données sur l'utilisation des antibiotiques ont été recueillies via un questionnaire rempli lors d'un entretien réalisé sur les lieux. La grande majorité des antibiotiques étaient administrés dans la nourriture. L'association chlortétracycline/sulfaméthazine/pénicilline et la tylosine étaient les plus fréquemment utilisés dans les aliments chez les naisseurs et les engraisseurs/finisseurs respectivement. L'utilisation d'antibiotiques dans l'eau a été rapportée, le plus souvent occasionnellement, dans toutes les catégories. L'utilisation d'antibiotiques injectables a été rapportée le plus souvent chez les porcs malades. La pénicilline était l'antibiotique le plus fréquemment utilisé dans l'eau ou en injection. La faible fréquence d'utilisation d'antimicrobiens d'importance cruciale chez l'homme (quinolones et céphalosporines de 3^{ième} génération) est un fait encourageant du point de vue de la santé publique. L'étendue et la fréquence rapportée de l'utilisation de pénicilline et de tétracycline constitue une préoccupation pour la santé publique du fait que ces 2 antibiotiques sont également utilisés à des fins thérapeutiques en médecine humaine.

(Traduit par Docteur André Blouin)

Can Vet J 2006;47:446–452

Introduction

Antibiotic use in food animals is associated with substantial benefits, but also with potential public health risks (1–10). In swine, antibiotics are used to treat and prevent disease in swine, to protect swine welfare, and to improve growth rate and efficiency of feed utilization (1–2,9–10). The potential public health risks related to the use of antibiotics in swine and other food animals include the contamination of food with drug residues, release of drug residues into the environment, the selection for antibiotic resistant bacteria, and an occupational exposure of farmers and others to drugs (1–3,11). Although much of the antibiotic resistance observed in important human pathogens may be ascribed to use of antibiotics in human medicine, the use of antibiotics in agri-food production is also believed to contribute to this global public health problem (1,3–7).

Appropriate assessments of the selective pressure imposed by various types of antibiotic use in food animals are necessary to understand and anticipate antibiotic resistance trends in human and animal populations and in the environment (1,12–14). Periodic audits and statistically based surveys of end-users of food animal antibiotics, namely veterinarians and livestock producers, are suggested as relevant sources of information regarding the use of antibiotics in food animal production (15).

There is little published farm-level information about antibiotic use in food animals. In Canada, the use of

Food Safety Division, Alberta Agriculture, Food and Rural Development, Edmonton, Alberta T7H 4P2 (Rajić); Laboratory for Foodborne Zoonoses, Public Health Agency of Canada, Guelph, Ontario N1G 3W4 (Reid-Smith, Deckert); Department of Population Medicine, University of Guelph, Ontario N1G 2W1 (Rajic, Reid-Smith, Deckert, Dewey, McEwen).

Address all correspondence and reprint requests to Dr. Rajić; e-mail:andrijana_rajic@hc-sc.gc.ca

Dr. Rajic's current address is Laboratory for Foodborne Zoonoses, Public Health Agency of Canada, 110 Stone Road West, Guelph, Ontario N1G 3W4.

Funding for this project was provided by the Food Safety Division, Alberta Agriculture, Food and Rural Development, Edmonton, Alberta, Canada and the Government of Canada, through the Western Economic Development Fund, Canada.

antibiotics in swine has been described most extensively in Ontario (16–17). However, swine production systems differ substantially among provinces, so the information from Ontario may not be representative of that for the entire Canadian swine population. No Canadian study conducted to date has investigated the use of antibiotics in western Canada, using a farm-based questionnaire. Thus, the purpose of this study was to describe the antibiotic use patterns and the types of antibiotics used through various phases of production reported by 90 swine operations in Alberta. Collection of information on specific dosing regimes was beyond the scope of the study.

Materials and methods

General aspects of the study

A study was conducted in Alberta from May to September 2000, with the objective of determining the prevalence and serovar diversity of *Salmonella* spp. in finisher pigs and the risk factors for *Salmonella* infections on 90 swine finisher farms. Methods utilized for the selection of these farms have been described in detail elsewhere (18). In brief, 10 veterinary practitioners selected 90 swine farms in Alberta, based on an annual production of $\geq$ 2000 market pigs per farm and the willingness of the producers to participate in the study.

Data on antibiotic use were collected by using a questionnaire designed to determine the management practices of participating farms. The questionnaire (copy available from the first author upon request) comprised 4 sections: production system and management, antibiotic use, health status, and biosecurity. Multisite operation was defined as a corporate enterprise with $\geq$ 2 sites. Other operations (farrow-to-finish, farrow-to-wean, individual grow-to-finish, or finishing farms) referred to owner operated facilities. The questionnaire was pretested by 3 pork producers, 3 provincial pork extension specialists, and 3 veterinarians who were familiar with the survey technique. The owner or operator of the farm completed the questionnaire with his or her herd veterinarian.

Collection of antibiotic use and farm health information

The questionnaire included a 4-page section on the use of antibiotics consisting of 3 subsections. In the 1st subsection, respondents were asked to indicate for weaners, growers, and finishers the percentage (%) of time that antibiotics were added to feed during the past 12 mo (summer 1999 to summer 2000) by using the following response options: never, occasionally ($<$ 50%), frequently (50% to 95%) and always ($>$ 95%). They were also asked to specify, from a list of trade and generic names, the types of in-feed antibiotics used in feeds of weaners, growers, and finishers, during the past 12 mo. In the 2nd subsection, respondents were asked to indicate the percentage of time for weaners, growers, finishers, and sows that antibiotics were added to water during the past 12 mo by using the same response options as described above. They were also asked to specify, from a list of trade and generic names, the types of in-water antibiotics used for those categories during the past 12 mo. In the 3rd subsection, respondents were asked to indicate, from a list of trade and generic names, the types of specific injectable antibiotics used during the past 12 mo for weaners, growers, and finishers by using the following response options: whole barn, whole pen, and sick pigs only.

A 1-page section on the disease status of the herd included a list of 16 diseases and their respective agents that are frequently observed on commercial swine farms in North America. Respondents were asked to indicate which of those diseases had been diagnosed in the various pig categories by the herd veterinarian, diagnostic laboratory, or both, during the 12 mo preceding the survey by using the following response options: never, occasionally, and commonly.

Table 1. Number (%) of farms in which any antibiotic use was reported through feed, water, and injection in various phases of production in 90 swine farms in Alberta in 2000

Antibiotic route of administration	Number (%) of farms administering antibiotics in this fashion during the past 12 mo		
	Weaners[a]	Growers[b]	Finishers[c]
Feed	76 (100) (95%–100%)[d]	80 (90.9) (83%–96%)[d]	72 (80.0) (70%–88%)[d]
Water	38 (50.0) (38%–62%)[d]	18 (20.5) (13%–30%)[d]	16 (17.8) (11%–27%)[d]
Injection	65 (85.5) (76%–93%)[d]	62 (70.5) (60%–80%)[d]	50 (55.6) (45%–66%)[d]

[a]Weaning phase of 76 farrow-to-finish farms
[b]Growing phase of 76 farrow-to-finish farms, 6 individual grow-to-finish farms, and 6 grow-to-finish farms within multisite operations
[c]Finishing phase of 76 farrow-to-finish farms, 6 individual grow-to-finish farms, 6 grow-to-finish farms within multisite operations, and 2 finishing farms
[d]95% confidence intervals

Data manipulation and statistical analyses

Questionnaire data were entered into a spreadsheet program (Microsoft Excel 2000; Microsoft Corporation, Redmond, Washington, USA). Data were verified for accuracy by checking each entry against the original hard copy data and then transferred into a statistical software package (Statistix version 2000; STATISTIX Analytical Software, St. Paul, Minnesota, USA) for descriptive statistical analyses. The frequencies and percentages of farms reporting the use of antibiotics through feed, water, and injection were computed for various production phases. Descriptive measures were also computed for the types of antibiotics that were reported to have been administered through feed, water, and injection in various production phases during the previous 12 mo. Confidence intervals for proportions were obtained by using the exact binomial distributions option of a statistical software program (Stata Intercooled, version 8; Stata Corporation, College Station, Texas, USA).

Results

Brief farm description

The annual production of the farms studied represented approximately 25% of the market swine production in Alberta. Participating farms were geographically

Table 2. The most frequent in-feed antibiotic use patterns reported by 76 farrow-to-finish swine farms in Alberta in 2000[a]

Number of farms (%)	% of time antibiotics added to feed during the past 12 mo											
	Weaners				Growers				Finishers			
	0	< 50	50–95	> 95	0	< 50	50–95	> 95	0	< 50	50–95	> 95
47 (61.8)				+				+				+
8 (10.5)				+				+			+	
8 (10.5)				+				+	+			
6 (7.8)				+	+				+			

[a]Other in-feed antibiotic use patterns were reported by ≤ 2 participating farrow-to-finish farms

representative of the major swine production areas in Alberta. Seventy-six (84.4%) farms were farrow-to-finish, while 6 (6.7%), 6 (6.7%), and 2 (2.2%) farms were multisite operations, grow-to-finish and finisher, respectively. Among farrow-to-finish and multisite operations, the number of sows per farm ranged from 100 to 3000 (mean = 525, median = 300). The information on the disease status was incomplete, because 3 practitioners declined to complete that section of the questionnaire for 24 participating farms for privacy reasons. Therefore, no statistical analysis was attempted to evaluate if reported disease status was associated with reported antibiotic use at the farm level.

Antibiotic use in feed

Table 1 shows the proportions of farms in which the use of antibiotics through feed was reported in various phases of production. Ten antibiotic in-feed use patterns were reported at the farm level among the 76 farms that raised weaners, growers, and finishers. The most frequent antibiotic use patterns among the 76 farrow-to-finish farms are shown in Table 2.

Weaners

The use of antibiotics through feed was reported > 95%, between 50% and 95%, and < 50% of the time in 73 (96.1%), 1 (1.3%), and 2 (2.6%) farrow-to-finish farms, respectively. The use of 1, 2, 3, 4, and 5 in-feed antibiotics was reported in 16 (21.1%), 8 (10.5%), 40 (52.6%), 8 (10.5%), and 3 (3.9%) farms, respectively. Two antibiotic drug combinations and 8 individual antibiotics were reported (Table 3).

Growers

The use of antibiotics through feed was reported > 95% of the time, between 50% and 95%, < 50%, and none of the time in 75 (85.2%), 3 (3.4%), 2 (2.3%), and 8 (9.1%) farms, respectively. The use of 1, 2, 3, 4, and 6 in-feed antibiotics was reported in 49 (55.7%), 22 (25.0%), 1 (1.1%), 7 (7.9%), and 1 (1.1%) farms, respectively. Two antibiotic drug combinations and 8 individual antibiotics were reported (Table 3).

Finishers

Antibiotic use through feed was reported > 95% of the time, between 50% and 95%, < 50%, and none of the time in 54 (60%), 13 (14.4%), 4 (4.4%), and 18 (20%) farms, respectively. The use of 1, 2, and 3 in-feed antibiotics was reported in 57 (63.3%), 13 (14.4%), and 1 (1.1%) farms, respectively. One antibiotic drug combination and 6 individual antibiotics were reported (Table 3).

Sows

The use of 1 in-feed antibiotic during the past 12 mo was reported most frequently. Two in-feed antibiotic drug combinations and 7 individual antibiotics were reported in lactating sows, whereas 1 in-feed antibiotic drug combination and 7 individual antibiotics were reported in dry sows (Table 3).

Antibiotic use in water

Table 1 shows the proportion of farms in which the use of antibiotics through water was reported in various production phases during the past 12 mo. Among these farms, mostly occasional antibiotic use was reported in all phases of production.

Weaners

The use of 1, 2, and 3 in-water antibiotics was reported in 25 (32.9%), 11 (14.5%), and 3 (3.9%) farms, respectively. Four antibiotic drug combinations and 4 individual antibiotics were reported (Table 4).

Growers

The use of 1 and 2 in-water antibiotics was reported in 15 (17.0%) and 3 (3.4%) farms, respectively. One antibiotic drug combination and 5 individual antibiotics were administered through water (Table 4).

Finishers

The use of 1 and 2 in-water antibiotics was reported in 14 (15.6%) and 2 (2.2%) farms, respectively. Four individual antibiotics were reported (Table 4).

Sows

In dry and lactating sows, only occasional use of antibiotics through water was reported in 4 (5.3%) and 1 (1.3%) farms, respectively, during the past 12 mo. Only 2 antibiotics were reported in these categories (Table 4).

Antibiotic use through injection

Table 1 gives the proportion of farms in which the use of antibiotics through injections was reported in various phases of production during the past 12 mo. One antibiotic drug combination and 5 individual antibiotics were reported in all production phases (Table 5). The use of injectable antibiotics limited to sick pigs only was reported in all phases of production. In weaners, the use

Table 3. Reported type of antibiotic used through feed in various phases of production in 90 swine farms in Alberta in 2000

Type of antibiotic	Number of farms (%) using this antibiotic				
	Weaners[a]	Growers[b]	Finishers[c]	L. Sows[d]	D. Sows[e]
Bacitracin	Ø	Ø	Ø	Ø	Ø
Carbadox	16 (21.1)[f] (13%–32%)[f]	4 (4.5) (1.3%–11%)[f]	Ø	Ø	Ø
Chlortetracycline	7 (9.2) (4%–18%)[f]	10 (11.4) (6%–20%)[f]	5 (5.6) (1.8%–12.4%)[f]	7 (9.2) (4%–18%)[f]	8 (10.5) (5%–20%)[f]
Chlortetracycline/ sulfamethazine/penicillin	45 (59.2) (47%–70%)[f]	5 (5.7) (1.9%–13%)[f]	Ø	6 (7.9) (3%–16%)[f]	3 (3.9) (0.8%–11%)[f]
Dimetridazole	1 (1.3) (0.03%–7%)[f]	7 (7.9) (3.2%–16%)[f]	Ø	6 (7.9) (3%–16%)[f]	8 (10.5) (5%–20%)[f]
Lincomycin	6 (7.9) (3%–16%)[f]	30 (34.1) (24%–45%)[f]	19 (21.1) (13%–31%)[f]	1 (1.3) (0.03%–7%)[f]	2 (2.6) (0.3%–9%)[f]
Lincomycin/ spectinomycin	12 (15.8) (8%–26%)[f]	1 (1.1) (0.03%–6%)[f]	2 (2.2) (0.3%–8%)[f]	1 (1.3) (0.03%–7%)[f]	Ø
Oxytetracycline	4 (5.3) (1.5%–13%)[f]	9 (10.2) (5%–19%)[f]	3 (3.3) (0.7%–9%)[f]	3 (3.9) (0.8%–11%)[f]	2 (2.6) (0.3–9%)[f]
Penicillin	4 (5.3) (1.5%–13%)[f]	4 (4.5) (1.3%–11%)[f]	2 (2.2) (0.3%–8%)[f]	2 (2.6) (0.3%–9%)[f]	2 (2.6) (0.3%–9%)[f]
Tilmicosin	Ø	Ø	1 (1.1) (0.03%–6%)[f]	Ø	Ø
Tiamulin	3 (3.9) (0.8%–11%)[f]	2 (2.7) (0.3%–8%)[f]	Ø	Ø	Ø
Tylosin	4 (5.3) (1.5%–13%)[f]	41 (46.6) (36%–58%)[f]	48 (53.3) (43%–64%)[f]	6 (7.9) (3%–16%)[f]	7 (9.2) (4%–18%)[f]
Virginiamycin	Ø	Ø	Ø	3 (3.9) (0.8%–11%)[f]	1 (1.3) (0.03%–7%)[f]

[a]Weaning phase of 76 farrow-to-finish farms
[b]Growing phase of 76 farrow-to-finish farms, 6 individual grow-to-finish farms, and 6 grow-to-finish farms within multisite operations
[c]Finishing phase of 76 farrow-to-finish farms, 6 individual grow-to-finish farms, 6 grow-to-finish farms within multisite operations, and 2 finishing farms
[d]Lactating sow phase of 76 farrow-to-finish farms
[e]Dry sow phase of 76 farrow-to-finish farms
[f]95% confidence intervals

of 1, 2, 3, 4, and 5 antibiotics was reported in 24 (31.6%), 16 (21.1%), 11 (14.5%), 13 (17.1%), and 1 (1.3%) farms, respectively. In growers, the use of 1, 2, 3, and 4 injectable antibiotics was reported in 20 (22.7%), 18 (20.5%), 13 (14.8%), and 11 (12.5%) farms, respectively. In finishers, the use of 1, 2, 3, 4, and 5 injectable antibiotics was reported in 18 (20%), 14 (15.6%), 9 (10%), 8 (8.9%), and 1 (1.1%) farms, respectively. The most commonly reported injectable antibiotics in weaners, growers, and finishers are shown in Table 5.

Discussion

According to the Canadian Pork Council's swine industry statistics for 2000 (19), Alberta had approximately 2200 swine farms in the year of the study and among those, approximately 75% had $<$ 527 pigs per farm, 18% had 527 to 2652 pigs, and 8% had $\geq$ 2653 pigs. The farm size of 527 to 2652 pigs and the farm size of $\geq$ 2653 pigs contributed 32.6% and 59.2% of Alberta annual market pig production, respectively, or 91.8% of the total of 1 566 500 pigs produced in Alberta. More than 50% of farms in Alberta were farrow-to-finish, and most of the grow-to-finish pigs were produced in the Red Deer, Lethbridge, and Drumheller areas (20). In this study, participating herds represented approximately 25% of the annual market pig production in Alberta and were geographically representative of the major swine production areas in Alberta. Ten (7 swine only and 3 mixed animal practitioners) of the 16 veterinary practitioners in Alberta with swine clients participated in the study; they included all of the veterinarians who work exclusively with swine, thus indicating that the study had a good coverage of swine veterinary practices in Alberta. Consequently, the results should be generally representative of the larger ($\geq$ 2000 market pigs/y) swine farms in Alberta. However, considerable caution must be exercised before attempting to generalize the findings beyond these farms, because farms producing fewer than 2000 market pigs/y were not included in the study and participating farms were not selected randomly.

No attempt was made to discriminate between 'over-the-counter' and 'prescription' antibiotic use in participating herds, thus no inferences should be made regarding prescription practices of swine veterinarians in Alberta.

The finding that the vast majority of antibiotics were used in-feed is consistent with results of previous surveys conducted in the USA and Canada (16,21–22). This practice was more frequently reported in weaners than in other categories, supporting findings of the previous studies (1,16,21) that most pigs receive antibiotics

Table 4. Reported type of antibiotic used through water in various production phases in 90 swine farms in Alberta in 2000

Type of antibiotic	Number of farms (%) using this antibiotic				
	Weaners[a]	Growers[b]	Finishers[c]	L. Sows[d]	D. Sows[e]
Dimetridazole	Ø	4 (4.5) (1.3%–11%)[f]	4 (4.4) (1.2%–11%)[f]	Ø	Ø
Lincomycin	Ø	1 (1.1) (0.03%–6%)[f]	Ø	Ø	Ø
Lincomycin/ spectinomycin	1 (1.3) (0.03%–7%)[f]	Ø	Ø	Ø	Ø
Neomycin/tetracycline	4 (5.3) (1.5%–13%)[f]	Ø	Ø	Ø	Ø
Oxytetracycline	1(1.3) (0.03%–7%)[f]	Ø	Ø	Ø	Ø
Penicillin	28 (36.9) (26%–49%)[f]	9 (10.2) (5%–19%)[f]	8 (8.9) (4%–17%)[f]	1 (1.3) (0.03%–7%)[f]	3 (3.9) (0.8%–11%)[f]
Penicillin/streptomycin	4 (5.3) (1.5%–13%)[f]	Ø	Ø	Ø	Ø
Sulphamethazine	3 (3.9) (0.8%–11%)[f]	1 (1.1) (0.03%–6%)[f]	1 (1.1) (0.03%–6%)[f]	Ø	Ø
Tetracycline	3 (3.9) (0.8%–11%)[f]	4 (4.5) (1.3%–11%)[f]	4 (4.4) (1.2%–11%)[f]	Ø	1 (1.3) (0.03%–7%)[f]
Tiamulin	3 (3.9)[f] (0.8%–11%)[f]	Ø	Ø	Ø	Ø
Trimethoprim/sulfadoxin	3 (3.9) (0.8%–11%)[f]	1 (1.1) (0.03%–6%)[f]	Ø	Ø	Ø
Tylosin	Ø	Ø	Ø	Ø	Ø

[a]Weaning phase of 76 farrow-to-finish farms
[b]Growing phase of 76 farrow-to-finish farms, 6 individual grow-to-finish farms, and 6 grow-to-finish farms within multi-site operations
[c]Finishing phase of 76 farrow-to-finish farms, 6 individual grow-to-finish farms, 6 grow-to-finish farms within multi-site operations, and 2 finishing farms
[d]Lactating sow phase of 76 farrow-to-finish farms
[e]Dry sow phase of 76 farrow-to-finish farms
[f]95% confidence intervals

in-feed after weaning ("starter rations"), when they are most vulnerable to infectious diseases. Dunlop et al (16) surveyed 639 farms in Ontario in 1991 and found that 94% of starter feeds contained antibiotics. Bush et al (22) investigated the use of antibiotics in 895 swine operations in the USA in 2000 and found that 82.7% of farms that raised nursery pigs added antibiotics to the feed for growth promotion or disease prevention purposes.

The use of antibiotics through feed was reported in a higher percentage of farms in growers (90.9%) and finishers (80%) in the present study than in the previous surveys (16,22). The use of in-feed antibiotics in finishers was reported in approximately 30% of 639 swine operations in Ontario (16), while approximately 57% and 37.9% of the 895 USA operations with grower and finisher pigs, respectively, included antibiotics in the feed for growth promotion and disease prevention (22). Dewey et al (23) reported that large and intermediate swine farms in the USA were more likely to use feed additives in the rations than were small farms with less than 50 sows, while producers who did not use veterinary consultants were 2.1 times more likely to use feed without feed additives. In this study, all farms had $\geq$ 100 sows (mean = 525, median = 300) and all producers used veterinary consultants, suggesting that the size of participating farms and the presence of veterinary consultants may, at least partially, account for the higher percentage of farms using in-feed antibiotics.

In the current study, the use of multiple (3 or more) in-feed antibiotics was frequently reported in weaners (67.1%) and infrequently in growers (10.2%) and finishers (1.1%). Dunlop et al (16) also reported that starter rations in swine farms in Ontario often contained $>$ 1 type of antibiotic, while relatively few operations added $>$ 1 antibiotic to finisher feed. While the tetracycline/sulfamethazine/penicillin and the carbadox and lyncomycin/spectinomycin combinations were the most commonly used in-feed antibiotics in weaners in this study (Table 3), tylosin, carbadox, and furazolidone were the most commonly used in-feed antibiotics in the Ontario study (16). It is important to note that furazolidone and carbadox were removed from the Canadian market for use in swine in Canada in 1994 and 2001, respectively. Our finding that tylosin and lincomycin were the most commonly reported in-feed antibiotics in growers and finishers (Table 3) is consistent with the previous surveys (16,22).

We observed that antibiotics were less frequently administered through water than through feed (Table 1). Among the farms using antibiotics in water, occasional use of only 1 type of antibiotic was reported mostly, particularly in growers and finishers. Previous surveys

Table 5. The types of injectable antibiotics reported in various production phases in 90 swine farms in Alberta in 2000

Type of antibiotic	Number (%) of farms using this antibiotic		
	Weaners[a]	Growers[b]	Finishers[c]
Ceftiofur	10 (13.2) (6.5%–23%)[d]	4 (4.6) (1.3%–11%)[d]	9 (10) (5%–18%)[d]
Lyncomycin	3 (3.9) (0.8%–11%)[d]	3 (3.4) (0.7%–10%)[d]	3 (3.3) (0.7%–9%)[d]
Penicillin	45 (59.2) (47%–70%)[d]	50 (56.8) (46%–67%)[d]	37 (41.1) (31%–52%)[d]
Oxytetracycline	19 (25.0) (16%–36%)[d]	20 (22.7) (14%–33%)[d]	18 (20.0) (12%–30%)[d]
Trimethoprim/ sulfadoxine	28 (36.8) (26%–49%)[d]	12 (13.6) (7%–23%)[d]	13 (14.4) (8%–23%)[d]
Tylosin	7 (9.2) (4%–18%)[d]	14 (15.9) (9%–25%)[d]	10 (11.1) (5%–19%)[d]

[a]Weaning phase of 76 farrow-to-finish farms
[b]Growing phase of 76 farrow-to-finish farms, 6 individual grow-to-finish farms, and 6 grow-to-finish farms within multisite operations
[c]Finishing phase of 76 farrow-to-finish farms, 6 individual grow-to-finish farms, 6 grow-to-finish farms within multisite operations, and 2 finishing farms
[d]95% confidence intervals

(16,22) investigated the use of antibiotics in the grow-finish phase of production only and reported that 25.3% and 33.3% of farms in Ontario and the USA, respectively, included antibiotics in water in those categories, mostly for therapeutic purposes. While penicillin was the most frequent in-water antibiotic in growers and finishers in our study (Table 4), dimetridazole and tetracycline were the most frequent in-water antibiotics in the Ontario and the United States' studies, respectively (16,22).

In the United States' study (22), approximately 66.6% of the production units administered injectable antibiotics to grower and finisher pigs, primarily to treat respiratory disease. The most common strategy for all categories was to treat all pigs in a room initially and then to treat only the clinically ill pigs. In the present study, the use of injectable antibiotics was mostly reported only in sick pigs for all production phases. It has been estimated that injection site damages cost the American pork industry approximately US$40 million annually as a result of trim loss at packing plants (24). The use of injectable antibiotics was less frequently reported in growers and finishers than in weaners in this study (Table 1), possibly this type of use was avoided in certain farms to prevent injection-related side effects and tissue damage at the injection sites. Difficulties in handling larger pigs, lower morbidity, and lower individual pig observation rates in pigs of this age might also account for the less frequent use of injectable antibiotics in these categories. We observed the use of multiple injectable antibiotics in all production phases, which was consistent with findings reported in the Ontario study (16). The ranking of injectable antibiotics in growers and finishers (Table 5) was consistent with those reported in the Ontario and United States' studies (16,22).

An important limitation of the study is that information on the type of use (therapeutic or growth promotion), duration of the treatment (d) for specific types of use, and the dose were not acquired, because logistical constraints required brevity in the questionnaire. It would be beneficial to obtain this information through further studies or prospective ongoing antibiotic use monitoring, considering that in-feed antibiotic use is a practice that has been shown to be a risk factor in the development of antibiotic resistance (25). The apparent low frequency of use of critically important antibiotics for use in humans (fluoroquinolones and 3rd generation cephalosporins) is an encouraging finding from a public health perspective (3,7,11,15,25). However, the widespread and frequently reported use of penicillin and tetracycline are of public health concern, considering that both antibiotics are also used for therapeutic purposes in human medicine (1,3–7,25). Furthermore, these less expensive antibiotics have been used to protect animal health for decades (1–2), indicating a need to utilize these antibiotics more judiciously, if their benefits are to be preserved.

The most continuous use of in-feed antibiotics in weaners reported in a large percentage (96.1%) of farms was expected. We were somewhat surprised that such use was also reported in growers and finishers in 85.2% and 60.0% of farms, respectively, indicating that at least a certain percentage of the use may be for growth promotion purposes. Unfortunately, the disease status for participating farms was incomplete, because 3 practitioners declined to provide this information for 24 herds due to confidentiality reasons. This introduced a significant bias to this information and prevented analyses on potential associations between the herd antibiotic use and the herd disease status. According to the Ontario study (16), only 10% of producers thought that feeding antibiotics to healthy finishers could be profitable. When the effects of various regimens for the administration of antibiotics in feed were evaluated in multisite production systems (26), only the growth rate of nursery pigs was significantly improved, while the growth rate of finishers and the feed efficiency of nursery and finishing pigs were not significantly improved. Based on these findings, Dritz et al (26) have recommended that the use of antibiotics for growth promotion should be limited to the nursery phase in multisite production systems. Initial experiences from the European Union have indicated that the ban of antibiotic growth promoters in swine did not have any measurable impact on pig health in the growing and finishing phases, while only minor effects on performance were observed (27,28). However, negative effects were reported in weanling pigs due to the increased prevalence of postweaning diarrhea, consequently increasing therapeutic use of antibiotics (25). In the present study, no in-feed antibiotic use was reported in finishers in 18 (20%) mostly farrow-to-finish farms, indicating that this category may be a reasonable target for voluntary reduction or cessation of nontherapeutic antibiotic use. This would have an immediate positive economic impact on the swine industry, as these additives represent a substantial portion of the expenses associated with feeding pigs (26). There is also a potentially positive public health impact, as reduced antibiotic use would also reduce the pressure for selection of antibiotic-resistant bacteria (3,6,7,15,25–27). This proactive approach, along with a rigorous judicious use of antibiotics in swine (29), would allow the swine industry to preserve the benefits of existing antibiotics and to evaluate actual economic and public health impacts of

reduced antibiotic use in various production systems. However, other researchers warn that the banning of any antibiotic usage in animals based on the "precautionary principle" in the absence of a full quantitative risk assessment is likely to be wasted at best and even harmful to both animal and human health (30).

The frequency of use of antibiotics commonly administered through feed, water, and, to a lesser extent, injection differed from those observed in the previous surveys (16,21–22), indicating the importance of local industry information when assessing public health risks associated with the use of antibiotics. Antibiotic use patterns in the swine industry may vary over time. Therefore, periodically conducted surveys would be useful for monitoring patterns of antibiotic use and for understanding or anticipating the emerging antibiotic resistance patterns. Data on the use of antibiotics in swine and other food animals are essential for evaluating risks associated with the use of antibiotics in food animals, as well as for the design and planning of monitoring programs and ongoing management at the individual farm, district, regional, national, and international levels.

Acknowledgments

The authors thank all participating swine producers and veterinarians from Alberta. The authors acknowledge the assistance from Annette Visser and Christine Duffy, technical and administrative staff of the Agri-Food Systems Branch, Food Safety Division (FSD), Alberta Agriculture, Food and Rural Development (AAFRD). CVJ

References

1. McEwen SA, Fedorka-Cray PJ. Antimicrobial use and resistance in animals. Clin Infect Dis 2002;34:S93–S106.
2. Friendship RM. Antimicrobial drug use in swine. In: Prescott JF, Baggot JD, Walker RD, eds. Antimicrobial Therapy in Veterinary Medicine. 3rd ed. Iowa State Univ Pr, 2000:602–611.
3. van den Bogaard AE, Stobberingh EE. Antimicrobial usage in animals. Impact on bacterial resistance and public health. Drugs 1999;58:589–607.
4. Hardy B. The issue of antibiotic use in the livestock industry: what have we learned? Anim Biotechnol 2002;13:129–147.
5. Teale CJ. Antimicrobial resistance and the food chain. J Appl Microbiol Symp Suppl 2002;92:85S–89S.
6. McDermott PF, Zhao S, Wagner DD, Simjee S, Walker RD, White DG. The food safety perspective of antibiotic resistance. Anim Biotechnol 2002;13:71–84.
7. World Health Organization (WHO) [page on the internet] WHO Drug Information [c2001 WHO.OMS] Antimicrobial resistance search. The medical impact of the use of antimicrobials in food animals. Report of a WHO meeting, Berlin, Germany 1997. Available at: http://www.who.int/medicentre/factsheets/fs.194/en/ Last accessed October 31, 2005.
8. Threlfall EJ, Ward LR, Frost JA, Willshaw GA. The emergence and spread of antibiotic resistance in food-borne bacteria. Int J Food Microbiol 2000;62:1–5.
9. Cromwell GL. Why and how antibiotics are used in swine production. Anim Biotechnol 2002;13:7–27.
10. Mackinnon JD. The proper use and benefits of veterinary antimicrobial agents in swine practice. Vet Microbiol 1993;35:357–367.
11. Berends BR, Van Den Bogaard AEJM, Van Knapen F, Snijders JMA. Human health hazards associated with the administration of antimicrobials to slaughter animals. Part II. An assessment of the risks of resistant bacteria in pigs and pork. Vet Q 2001;23:10–21.
12. Witte W. Selective pressure by antibiotic use in livestock. Int J Antimicrob Agents 2000;16:S19–S24.
13. Stege H, Bager F, Jacobsen, Thougaard A. VETSTAT — the Danish system for surveillance of the veterinary drugs for production animals. Prev Vet Med 2003;57:105–115.
14. Chauvin C, Beloeil PA, Orand JP, Sanders P, Madec F. A survey of group-level antibiotic prescriptions in pig production in France. Prev Vet Med 2002;55:109–120.
15. World Organization for Animal Health. Antimicrobial resistance. Reports prepared by the OIE Ad hoc Group of experts on antimicrobial resistance. Sci Tech Rev 2001;20:797–870.
16. Dunlop RH, McEwen SA, Meek AH, Friendship RA, Clarke RC, Black WD. Antimicrobial drug use and related management practices among Ontario swine producers. Can Vet J 1998;39:87–96.
17. Dunlop RH, McEwen SA, Meek AH, Clarke RC, Black WD, Friendship RM. Individual and group antimicrobial usage rates on 34 farrow-to-finish farms in Ontario, Canada. Prev Vet Med 1998; 34:247–264.
18. Rajić A, Keenliside J, McFall ME, et al. Longitudinal study of *Salmonella* species in 90 Alberta swine finishing farms. Vet Microbiol 2005;105:47–56.
19. Canadian Pork Council [page on the internet] Statistics, Description of Canadian Hog Farms. Available at: http://www.cpc-ccp.com/stats.html Last accessed May 7, 2004.
20. Alberta Agriculture Food and Rural Development. Alberta Government [page on the internet]. Livestock, Pigs; Industry overview. Alberta's Pork Production Industry. Available at: http://www.agric.gov.ab.ca Last accessed October 31, 2005.
21. Dewey CE, Cox BD, Straw BE, Bush EJ, Hurd HS. Use of antimicrobials in swine feeds in the United States. J Swine Health Prod 1999;7:19–25.
22. Bush EJ, LeRoy-Biehl G. Use of antibiotics and feed additives in weaned market pigs by U.S. pork producers. Proc Am Assoc Swine Vet Annu Meet, Kansas City, USA, 2002:329–331.
23. Dewey CE, Cox BD, Straw BE, Bush EJ, Hurd HS. Associations between off-label feed additives and farm size, veterinary consultant use, and animal age. Prev Vet Med 1997;31:133–146.
24. Kolb JR. Vaccination and medication via drinking water. Compend Contin Educ Pract Vet 1996;18:S75.
25. Prescott JF. Antimicrobial drug resistance and its epidemiology. In: Prescott JF, Baggot JD, Walker RD, eds. Antimicrobial Therapy in Veterinary Medicine. 3rd ed. Iowa State Univ Pr 2000:27–49.
26. Dritz SS, Tokach MD, Goodband RD, Nelssen JL. Effects of administration of antimicrobials in feed on growth rate and feed efficiency of pigs in multisite production systems. J Am Vet Med Assoc 2002;220:1690–1695.
27. World Health Organization (WHO) [page on the Internet] Health topics, Search Antimicrobial growth promoters. International review panel evaluation of the termination of the use of antimicrobial growth promoters in Denmark. World Health Organization, 2003. Available at: http://www.who.int/ Last accessed October 31, 2005.
28. Stein HH. Experience of feeding pigs without antibiotics: a European perspective. Anim Biotechnol 2002;13:85–95.
29. American Association of Swine Practitioners' Pharmaceutical Issues Committee. American Association of Swine Practitioners Basic Guidelines of Judicious Therapeutic Use of Antimicrobials in Pork Production. J Swine Health Prod 2000;8:90–93.
30. Phillips I, Casewell M, Cox T, et al. Does the use of antibiotics in food animals pose a risk to human health? A critical review of published data. J Antimicrob Chemother 2004;53:28–52.